

Approved for public release; distribution is unlimited.

The Impact of Integrating Modeling and Simulation Into Army Operational Test and
Evaluation

by

Brad R. Naegle
Lieutenant Colonel, U.S. Army
BS, Weber State University, 1977

Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL

September 1994



REPORT DOCUMENTATION PAGE

Form Approved OMB No 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.

1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE September 1994.		3. REPORT TYPE AND DATES COVERED Master's Thesis	
4. TITLE AND SUBTITLE THE IMPACT OF INTEGRATING MODELING AND SIMULATION INTO ARMY OPERATIONAL TEST AND EVALUATION (U)				5. FUNDING NUMBERS	
6. AUTHOR(S) Brad R. Naegle					
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey CA 93943-5000				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.					
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release: distribution is unlimited.				12b. DISTRIBUTION CODE A	
13. ABSTRACT (maximum 200 words) The purpose of this thesis is to analyze the integration of Modeling and Simulation (M&S) into the U.S. Army Operational Test and Evaluation (OT&E) process. The elements, shortfalls, and recurring problems associated with the OT&E system are examined with a focus on those that can be addressed by M&S. Current and future M&S architectures are outlined to provide a base of understanding for the applicability to the OT&E process and issues. Analysis of the potential strengths and weaknesses of M&S in addressing OT&E problems and issues are presented. Lessons learned from past OT&E efforts are also analyzed for process improvement through M&S integration. From this analysis, a set of recommendations in the area of M&S integration into Army OT&E are formulated and offered.					
14. SUBJECT TERMS Operational Test and Evaluation, Modeling and Simulation				15. NUMBER OF PAGES 90	
				16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL		

ABSTRACT

The purpose of this thesis is to analyze the integration of Modeling and Simulation (M&S) into the U.S. Army Operational Test and Evaluation (OT&E) process. The elements, shortfalls, and recurring problems associated with the OT&E system are examined with a focus on those that can be addressed by M&S. Current and future M&S architectures are outlined to provide a base of understanding for the applicability to the OT&E process and issues. Analysis of the potential strengths and weaknesses of M&S in addressing OT&E problems and issues are presented. Lessons learned from past OT&E efforts are also analyzed for process improvement through M&S integration. From this analysis, a set of recommendations in the area of M&S integration into Army OT&E are formulated and offered.

1 Res 13
N214
C,1

TABLE OF CONTENTS

I.	INTRODUCTION	1
A.	PURPOSE	1
B.	BACKGROUND	1
C.	THESIS OBJECTIVE	3
D.	RESEARCH QUESTIONS	3
E.	SCOPE AND LIMITATIONS	4
F.	RESEARCH LITERATURE AND METHODOLOGY	5
G.	ACRONYMS	6
H.	ORGANIZATION OF THESIS	6
II.	THE OT&E PROCESS	7
A.	GENERAL	7
1.	OT&E Missions and Definitions	7
2.	OT&E Organization	8
3.	OT&E Support to the Acquisition Process	10
B.	OT&E LAWS, REGULATIONS, AND DIRECTIVES	14
1.	Title 10, United States Code	15
2.	Department of Defense Instruction (DoDI) 5000.2	16
3.	Army Regulation 73-1, Test and Evaluation Policy	17
C.	CURRENT ARMY OT&E AND M&S INTEGRATION	18

D. OT&E ELEMENTS	18
1. Realism	18
2. User Oriented	19
3. Representative Systems	20
4. Sufficiency	21
E. SUMMARY	21
 III. ARMY MODELING AND SIMULATION THRUSTS	 23
A. GENERAL	23
B. DoD M&S POLICIES	25
C. M&S CONCEPTS AND APPLICATIONS	26
1. Model-Test-Model	27
2. Janus Combat Model	28
3. Semi-Automated Forces	29
4. Battlefield Distributed Simulation - Developmental	 30
5. Distributed Interactive Simulation	31
6. Defense Simulation Internet	33
D. BATTLE LABS	34
E. LOUISIANA MANEUVERS	37
F. SUMMARY	38
 IV. ANALYSIS	 40
A. GENERAL	40
B. METHODOLOGY	41
1. OT&E Weapon Systems	41

2. OT&E Problem and Issue Categories	42
a. OT&E Test Design Validation Category	43
b. Resource Constraints Category	44
c. System Component Stress Category	44
d. Safety and Environmental Concerns Category	44
e. Data Validity and Reliability Category	45
C. ANALYSIS OF M&S APPLICATION TO OT&E	45
1. TEST DESIGN	46
a. M1A2 Main Battle Tank	46
b. Javelin Missile	47
c. Air-to-Air Target Designator	49
d. AH-64D Longbow Apache	51
e. Test Design Summary	52
2. RESOURCE CONSTRAINTS	53
a. M1A2 Main Battle Tank, Air-to-Air Target Designator, and Javelin Missile	53
b. Multi-Spectral Combat Decoy	55
c. Resource Constraint Summary	55
3. SYSTEM COMPONENT STRESS	56
a. Air-to-Air Target Designator and AH-64D Longbow Apache	56
b. MELIOS	58
c. System Component Stress Summary	58
4. SAFETY AND ENVIRONMENTAL CONCERNS	59

a.	Air-to-Air Target Designator and AH-64D Longbow Apache	59
b.	M1A2 Main Battle Tank, Javelin Missile, and AH-64D Longbow Apache	60
c.	Safety and Environmental Concerns Summary	61
5.	TEST DATA VALIDITY AND RELIABILITY	62
a.	Multi-Spectral Combat Decoy and MELIOS .	62
b.	M1A2 Main Battle Tank and Air-to-Air Target Designator	63
c.	Data Validity and Reliability Summary .	64
D.	SUMMARY	65
V.	CONCLUSIONS AND RECOMMENDATIONS	66
A.	INTRODUCTION	66
B.	GENERAL CONCLUSIONS	67
C.	SPECIFIC CONCLUSIONS	69
1.	Test Design	69
a.	Current Problems and Issues	69
b.	M&S Solutions	69
2.	Resource Constraints	70
a.	Current Problems and Issues	70
b.	M&S Solutions	70
3.	System Component Stress	70
a.	Current Problems and Issues	70
b.	M&S Solutions	71

4. Safety and Environmental	71
a. Current Problems and Issues	71
b. M&S Solutions	72
5. Data Validity and Reliability	72
a. Current Problems and Issues	72
b. M&S Solutions	73
D. RECOMMENDATIONS	73
E. FURTHER RESEARCH	75
APPENDIX	77
LIST OF REFERENCES	79
INITIAL DISTRIBUTION LIST	81

I. INTRODUCTION

A. PURPOSE

The purpose of this thesis is to analyze the integration of Modeling and Simulation (M&S) into the U.S. Army Operational Test and Evaluation (OT&E) process. The elements, shortfalls, and recurring problems associated with the OT&E system are examined with a focus on those that can be addressed by M&S. From this analysis, a set of recommendations in the area of M&S integration into Army OT&E are formulated and offered. The recommendations address both cost effectiveness and adequacy of the integrated M&S approach to the OT&E process.

B. BACKGROUND

The modern battlefield requires continued advancement in virtually all complex weapon systems. Complex systems provide the accuracy, reduce the manpower requirement, and create the ability to control vast numbers of tasks simultaneously. They also produce a challenge to the OT&E process because they are extremely difficult to test in an operational environment. This difficulty is due to system complexity such as weapons tracking systems capable of identifying and tracking multiple targets or communications systems capable of simultaneously processing thousands of analog and digital messages. This

same advancing technology has also accelerated the development and useful application of M&S systems.

Modeling and simulation represents an explosive growth industry within the U.S. Department of Defense (DoD). The technologies comprising these revolutionary techniques are receiving increasingly wider application among the Services, and in particular the Army, as the DoD budget continues its rapid decline. As the cost of OT&E continues to increase with the complexity of the systems evaluated, the application of M&S to the OT&E process becomes ever more appealing. (Williams, 1993, p.16)

Counterbalancing the appeal of the relatively low cost M&S for OT&E applications are laws, directives, regulations and policies mandating live testing. In the test and evaluation community, there is a widely held distrust for anything that is "simulated" and the term itself brings to mind a circumvention of generally accepted testing protocols.

The connotation of any form of M&S within the test and evaluation communities is that shortcomings and failures of the evaluated system are being masked by the M&S effort. Furthermore, the human element is generally thought to be eliminated when M&S techniques are used. The following quote from Brigadier General Trifiletti, Commanding General of the U.S. Army Test and Experimentation Command (TEXCOM) illustrates some of the reasons M&S is not widely accepted:

The fog of war cannot be simulated by any computer. The effect of blisters on the feet of your soldiers, as well as most other human characteristics, are not portrayed in a simulation. You've got to get out on the ground with soldiers and equipment to understand the capabilities and limitations. (Trifiletti,1994)

C. THESIS OBJECTIVE

This thesis analyzes Army OT&E with a focus on M&S applications. The Army's current OT&E process is analyzed to identify persistent OT&E problems and issues, and assess current shortcomings that exist in OT&E. Where M&S concepts have potential application in enhancing OT&E elements or providing solutions for OT&E issues, analysis is offered as to the type, extent, and applicability of M&S concepts.

Analysis of the potential strengths and weaknesses of M&S in addressing the elements and issues associated with the OT&E process are presented. Lessons learned from past OT&E efforts are analyzed for possible process improvement through M&S integration. Supporting conclusions and recommendations based on the analysis of the thesis are presented.

D. RESEARCH QUESTIONS

The primary research question of this thesis is:

- To what extent can modeling and simulation address the recurring problems and issues associated with operational test and evaluation?

The four subsidiary research questions are:

- Does the operational test and evaluation process lend itself to integration with modeling and simulation?

- What current and proposed models and simulations are candidates for integration with operational test and evaluation?
- Can operational test and evaluation costs be reduced through the use of modeling and simulation?
- Can operational test and evaluation elements be enhanced through the use of modeling and simulation?

E. SCOPE AND LIMITATIONS

This thesis focuses on M&S applications within the U.S. Army OT&E process. The potential application of M&S in this thesis is limited to the test and evaluation phase of the acquisition process. Specifically, this thesis addresses OT&E rather than the developmental test and evaluation (DT&E) process.

This thesis identifies potential opportunities to integrate U.S. Army operational test and evaluation with current and future M&S applications in order to improve the Army OT&E process. The laws, regulations, directives, and policies pertaining to OT&E are examined to identify where M&S integration could be accomplished and under what circumstances that M&S is prohibited. Persistent issues surrounding OT&E on U.S. Army systems identified by experienced OT&E test personnel, are examined with emphasis on applying M&S as methods of resolving the issues.

Current and future M&S architecture is outlined to provide a base of understanding for the applicability to the OT&E

process and issues. Army wide M&S programs and applications across numerous commands are examined and presented.

Analysis of M&S integration opportunities includes limited cost analysis and other value added properties of M&S. Networked and distributed systems are emphasized in the M&S structure.

F. RESEARCH LITERATURE AND METHODOLOGY

Research data were obtained from official Government directives and policies, journals, previous theses, United States Code, DoD and Army regulations and manuals, and personal interviews. Information on current M&S programs was obtained from Army Training and Doctrine Command (TRADOC) Analysis Centers (TRACs), the Army's Simulation, Training and Instrumentation Command (STRICOM), and the Defense Modeling and Simulation Office (DMSO). Information on the U.S. Army operational test and evaluation process was obtained from the Operational Test and Evaluation Command (OPTEC) and the Test and Experimentation Command (TEXCOM). Current directives and policies guiding the OT&E process were reviewed.

Research was conducted via personal and telephone interviews with cognizant M&S and T&E personnel. Interviews with OT&E related individuals centered around the OT&E processes and the opportunities for M&S to enhance OT&E elements or address OT&E problems and issues. Interviews with

M&S related individuals focused on the state-of-the-art in M&S and their ability to address the OT&E process.

G. ACRONYMS

• An extensive listing of acronyms associated with both OT&E and M&S subjects is presented in the Appendix.

H. ORGANIZATION OF THESIS

Chapter II of this thesis addresses the OT&E process including OT&E unique elements. The laws, regulations, directives, and policies shaping the OT&E process are also presented to illustrate M&S opportunities and limitations in Army OT&E.

Chapter III provides an overview of the Army's M&S thrusts and the technologies involved in the M&S efforts. This chapter addresses both current and immediate future M&S opportunities that may have application in the OT&E arena.

Chapters IV and V, contain the analysis of M&S applications in the OT&E process and the conclusions and recommendations offered, respectively.

II. THE OT&E PROCESS

A. GENERAL

The most capable system is useless if it cannot be employed by the intended user within doctrine, force structure, tactics, and training programs. The OT&E process is designed to assess a system's effectiveness in a realistic, operational environment.

The purpose of this chapter is to delineate Army OT&E missions, definitions, and organizations. The current role of M&S in the OT&E process as well as the laws, directives, regulations, and policies guiding the Army OT&E process are addressed.

1. OT&E Missions and Definitions

The OT&E missions are: To determine the operational effectiveness and suitability of a system or to evaluate tactical and doctrinal concepts, under realistic combat conditions; and to determine if the minimum acceptable operational performance requirements, as specified in the Operational Requirements Document (ORD), have been satisfied. (DoDI 5000.2, 1991, p.8-5)

Operational effectiveness and suitability refers to the weapon system's combat effectiveness achieved when operated and maintained by typical users, within the intended

doctrine and tactics, and as part of standard organizations integrated with other battlefield operating systems. Operational effectiveness and suitability are distinct from weapon system capabilities (e.g., speed, range, armament penetration, etc.) determined during DT&E.

Realistic combat conditions are those that are representative of the environment, doctrine, level of training, and structure in which the evaluated system would normally be expected to operate within a combat environment. Realism is one of the critical elements of the OT&E process and is discussed in detail later in this chapter.

2. OT&E Organization

OT&E is organized as depicted in Figure 1. Congress passed legislation creating the Office of Operational Test and Evaluation in 1983 with the mission to evaluate the Services' weapon systems tests and assess test results. As part of that legislation, the Director of Operational Test and Evaluation (DOT&E) reports directly to the Secretary of Defense and is given broad authority to suspend major weapons programs that perform poorly in operational tests. In addition to reporting to the Secretary of Defense, the DOT&E reports directly to both the House and the Senate Armed Services Committees, at least annually, regarding OT&E of weapon systems being developed. The goal of the legislation

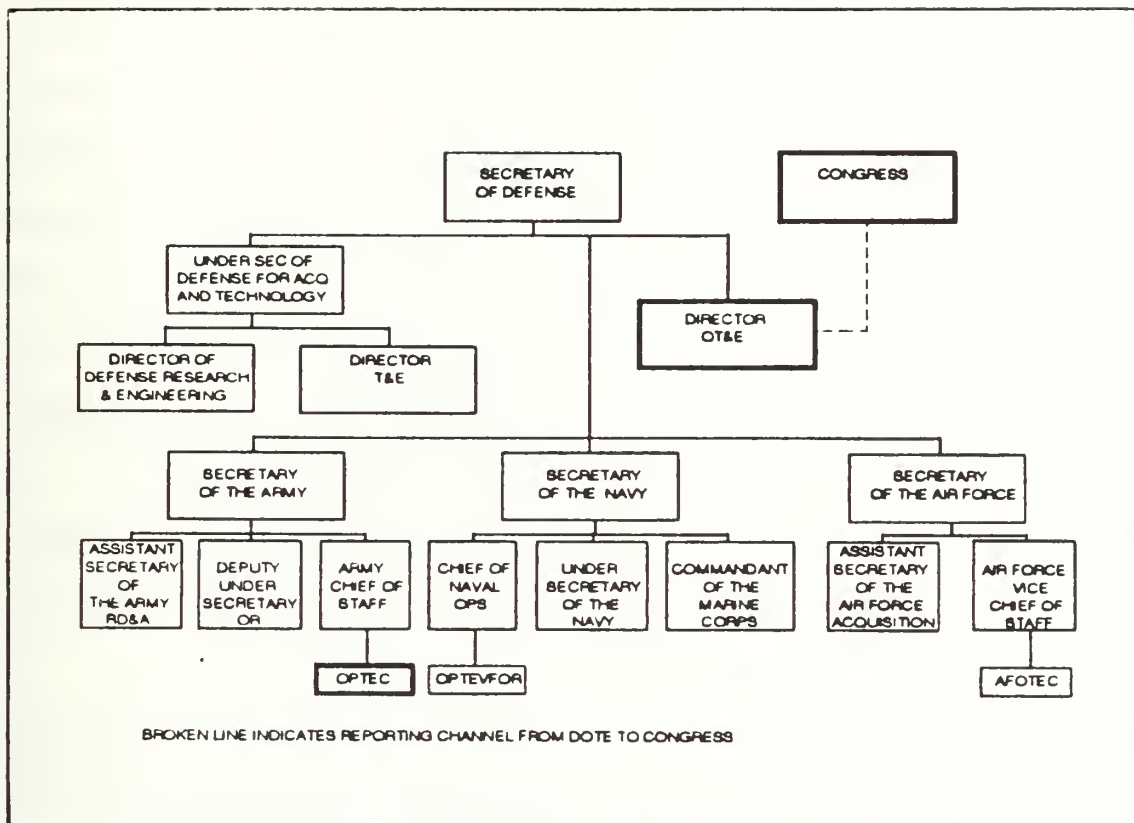


Figure 1 OT&E Organization

is to save time and money by exposing problems before expensive weapons are purchased and fielded.

The Operational Test and Evaluation Command (OPTEC) was established 15 November 1990 by Secretary of the Army General Orders Number 6. It consists of the OPTEC Headquarters and Support Agencies, the Operational Evaluation Command (OEC) and the Test and Experimentation Command (TEXCOM). The new command consolidates previously designated commands and agencies including the TRADOC Test and Experimentation Command (TEXCOM), the former Operational Test and Evaluation Agency (OTEA), and the former Acquisition and

Development of Threat Simulators Activity (ADATS-A) into a single command. ADATS-A, renamed the Operational Threat Support Activity (OTSA), and the Test and Evaluation Coordination Offices (TECOs), are incorporated within OPTEC Headquarters. OPTEC's mission is to conduct and monitor user test and evaluation (except medical) for the Army. User T&E includes initial and follow-on operational test and evaluation (IOTE and FOTE) in support of the materiel acquisition process, force development testing and experimentation (FDTE), concept evaluation program (CEP) trials, early user test and evaluation (EUTE), and the Army part of joint test and evaluation (JT&E).

OPTEC, Figure 2, is a field operating agency of the Office of the Chief of Staff of the Army. In keeping with the Defense Directives, OPTEC reports the results of Army OT&E through the Vice Chief of Staff of the Army directly to the Army and Defense leadership. The main part of OPTEC's mission is the planning, conducting, and reporting of Army OT&E which has been required by law since 1972. Additionally, OPTEC conducts tests for TRADOC in support of its mission to develop combat doctrine, organizations, and materiel requirements.

3. OT&E Support to the Acquisition Process

The materiel acquisition process can take many years from the time a materiel requirement is identified until the system is fielded. Although in this process, OT&E accounts

OPTEC

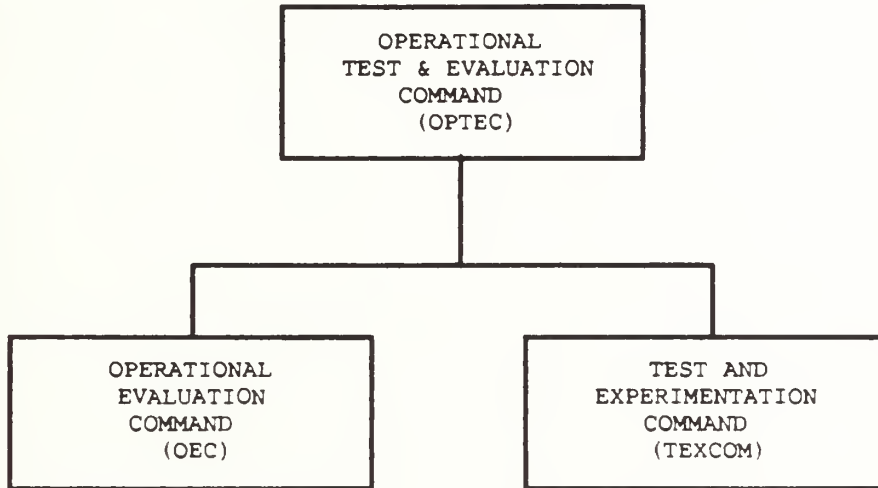


Figure 2 OPTEC Organizational Structure

for only a short time period, the results weigh heavily on the decisions to continue development, accept the system, or change organization, doctrine, and concepts.

The fundamental purpose of OT&E in the acquisition process is to identify the areas of risk associated with user requirements and acceptance to be reduced or eliminated. During the early phases of development, T&E is conducted to demonstrate the feasibility of conceptual approaches, minimize design risk, identify design alternatives, and estimate operational effectiveness and suitability. As a weapon system progresses through the developmental process, T&E emphasis

turns from DT&E towards OT&E, even though DT&E and OT&E may not be conducted sequentially. (DSMC TEMG,1988,p.1-1)

After a weapon system has successfully completed its development phase, there is tremendous political and bureaucratic pressure to begin full-scale production. The operational testers are often viewed as "show stoppers" because successful completion of OT&E is required before any developmental system can progress beyond low rate initial production (LRIP). The problem is compounded by the current acquisition process which schedules critical OT&E events just before the production decision milestone. (LeSueur,1994,p.12)

Figure 3 depicts Army OT&E events in each acquisition phase. The IOTE block includes CEP, EUTE, and FDTE events.

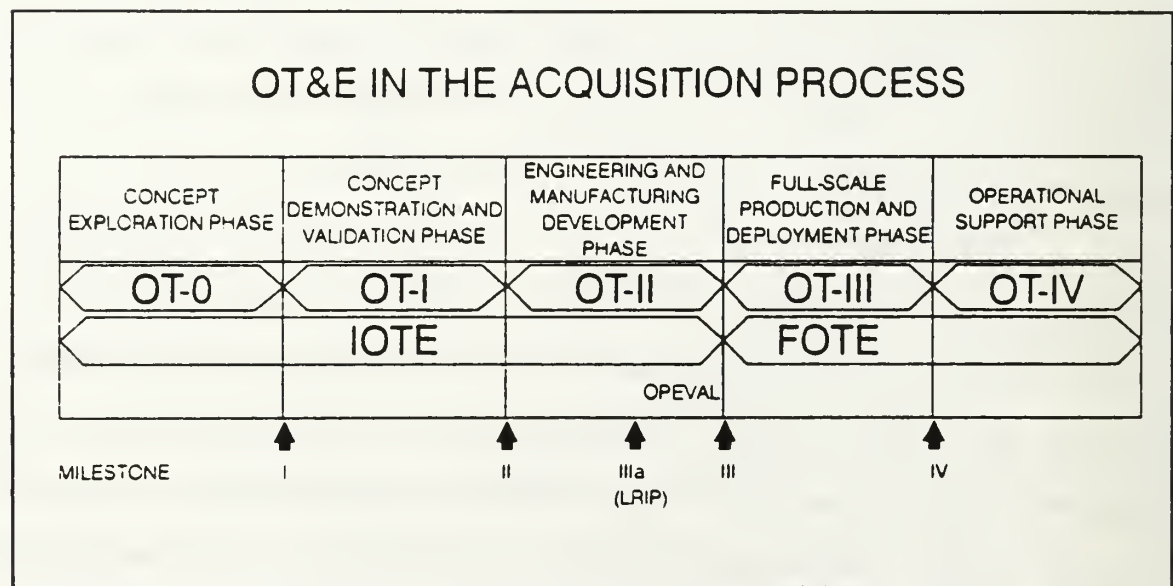


Figure 3 OT&E Support to the Acquisition Process

During the Concept Exploration Phase prior to Milestone I, laboratory testing, modeling and simulations are conducted to demonstrate and assess the capabilities of key subsystems and components. Studies, analyses, simulation, and test data are used to explore and evaluate alternative concept designs proposed to satisfy user generated requirements. OT&E conducted during this phase, called early operational assessment, investigates deficiencies identified during the mission area analysis. OPTEC monitors concept exploration T&E for future T&E planning and to provide effectiveness and suitability inputs desired by the Program Manager. Operational assessments addressing the operational impact of candidate technical approaches are conducted.

During the Concept Demonstration/Validation phase, operational effectiveness and operational suitability assessments are conducted. Information on tactics, doctrine, personnel requirements, and organization impacts of the weapon system are gathered. OT&E assessments are used to support the Milestone II decisions for developing promising alternatives.

The objective of the Engineering and Manufacturing Development phase is to design, fabricate and test systems that closely approximate the final product. Prior to the Milestone III decision, a dedicated OT&E is conducted on equipment formally certified as ready for "final OT&E". OT&E has the greatest impact on major programs in this phase because the decision to proceed beyond LRIP is contingent on

successfully completing the IOTE. A formal Operational Evaluation (OPEVAL) is required for Milestone III. The purpose of OT&E during this phase is to:

- Estimate the operational effectiveness and suitability of the system.
- Identify operational deficiencies.
- Recommend and evaluate changes in production configuration.
- Provide information for developing and refining logistics support requirements.
- Estimate the survivability of the system in the operational environment.

Post-production OT&E are Follow-on Operational Test and Evaluation (FOTE) programs designed to verify the operational effectiveness and suitability of the production system and to determine if deficiencies identified during IOTE have been corrected. FOTEs also refine doctrine, tactics, techniques, and training programs for the life of the system. (DSMC TEMG, 1988)

B. OT&E LAWS, REGULATIONS, AND DIRECTIVES

The OT&E process is guided by numerous laws, regulations, directives, and policies. The provisions of these mandates and guiding vehicles directly affect how the OT&E system plans, conducts, and analyzes evaluations. The role of M&S in the OT&E process is limited and, in some cases, precluded by the mandates guiding OT&E.

The current downsizing of the Army creates pressure to reduce costs at every level, including within the OT&E process. Even with these economic pressures, some lawmakers are continuing to guard against reductions in OT&E testing. In his article *Fallout: Weapons that don't work?*, Rick Maze reported the following:

Senators David Pryor (D-Ark) and William Roth (R-Del) said they oppose a Pentagon procurement reform plan that would allow operational tests to be waived if they are too expensive, cause long delays or otherwise interfere with the purchase of systems.

Pryor and Roth were the chief sponsors of the 1983 law that created the Pentagon's Office of Testing and Evaluation and remain committed to the principle that weapons need to be fully tested in live-fire exercises before large numbers are built. "It is a very important part of our military preparedness to make sure these weapons work", said Pryor. (Maze, 1994, p.20)

Law makers and policy makers have reinforced both the requirement for OT&E and the guiding documents addressed in the following paragraphs.

1. Title 10, United States Code

United States Code, Title 10, Chapter 138 has two sections that pertain to the OT&E process. Section 2399, *Operational test and evaluation of defense acquisition programs*, and section 2366, *Major systems and munitions programs: survivability and lethality testing; operational testing*.

Section 2399 establishes the conditions necessary for a major program (acquisition category I and II) to proceed

beyond LRIP and the DOTE reporting responsibilities. This law's provisions state that a major defense acquisition program may not proceed beyond low rate initial production (LRIP) until the Initial Operational Test and Evaluation (IOTE) for that program is complete. It further directs that the DOTE shall analyze the results of major systems' OT&E and prepare a report for the House and Senate Armed Services Committees and the Secretary of Defense. The report shall state the DOTE's opinion regarding OT&E adequacy and whether the results indicate that the evaluated system is effective and suitable for combat. (USC,1989,pp.230-231)

Section 2366 directs the Secretary of Defense to ensure that no major system proceed beyond LRIP until the IOTE and survivability/lethality testing is complete. This section specifically defines the conditions required for survivability and lethality testing. These conditions include the requirement for live firing on representative systems and therefore, preclude any major system from being acquired solely on the basis of M&S. Contractor and other personnel not normally involved in the operation or support of a weapon system, are forbidden to participate in OT&E under the provisions of this section. (USC,1989,pp.581-582)

2. Department of Defense Instruction (DoDI) 5000.2

This instruction references and reinforces the provisions of Title 10, United States Code, outlined in

paragraph one, above. It directs that OT&E shall be designed to support the decision to proceed beyond LRIP and establishes four objectives for OT&E testing:

- Provide essential information for assessment of acquisition risk and for decisionmaking.
- Verify attainment of technical performance specifications and objectives.
- Verify that systems are operationally effective and suitable for intended use.
- Provide essential information in support of decisionmaking.

With regard to the use of M&S in the OT&E process, DoDI 5000.2 interprets Title 10 in a strict manner. The Instruction states that OT&E does not include an operational assessment based exclusively on computer modeling, simulation, or analyses of program documents. (DoDI 5000.2,1991,p.8-2)

3. Army Regulation 73-1, Test and Evaluation Policy

Army Regulation 73-1 (AR 73-1) directs the implementation of DoD Directive 5000.1, DoD Instruction 5000.2, and DoD Manual 5000.2-M. This regulation describes the type of OT&E applications to be provided in support of each phase and milestone. It links T&E to the acquisition process and directs T&E design to support the acquisition phases and milestones. OPTEC is charged with the overall management of Army OT&E programs through use of an operational tester (TEXCOM) and an operational evaluator (OEC).

C. CURRENT ARMY OT&E AND M&S INTEGRATION

Through its stated policies, OPTEC recognizes the use of M&S to achieve adequate realism, support economical test execution, and provide for sufficiently adequate evaluations. However, to ensure that OPTEC maintains its objective, independent evaluator perspective, every M&S application used in the OT&E process must be subjected to Verification, Validation, and Accreditation (VV&A) before any data or information can be used. M&S applications must be accredited for each specific application, and the VV&A conducted for one OT&E does not apply to another. Because of the VV&A requirement, there is no listing or catalog of M&S applications available for use in the OT&E process. (OPTEC 73-21-1,1993)

D. OT&E ELEMENTS

The OT&E process is guided by operationally related test and evaluation elements. These elements are unique to the OT&E process and drive the design of all OT&E programs.

1. Realism

Realistic environments are essential to achieving the goals of OT&E. A realistic environment is one that is representative of the conditions, doctrine, level of training, and structure in which the evaluated system would normally be expected to operate, in a combat environment. These environments are distinctly different than those encountered

in the DT&E phase where the environment is carefully controlled.

Realism in the OT&E test process is affected by the resources available to replicate the representative threat and friendly force array, create the desired combat battlefield environment, and stress the evaluated system over time. Other factors affecting realism include the degree to which test participants represent typical operational personnel, test personnel familiarity with test ranges and maneuver areas, and limitations created by safety or environmental concerns.

The conditions present during the OT&E must stress the evaluated system within the doctrinal envelope of operation. "Stimulators" are used to stress communications and software intensive components of the evaluated system to levels expected in a combat environment.

An OT&E of a system includes its interoperability characteristics. A realistic structure of associated battlefield operating systems is essential.

2. User Oriented

An integral part of the OT&E process is the user. Representative personnel having the correct organizational grade and specialty structure, level of training, experience and aptitudes are required for an unbiased operational evaluation of the system.

Users include personnel that operate, maintain, support, or provide command and control functions affecting the evaluated system. This requires that the interrelated battlefield operating systems and the evaluated system's support structure personnel must also be representative.

The term "users" specifically excludes contractor and other personnel who would not normally be involved in the operation, control, or maintenance of the evaluated system. To avoid bias, it is important that the personnel selected to represent the user are indeed representative.

3. Representative Systems

The evaluated system equipment must be sufficiently mature to be considered functionally representative of the versions eventually fielded. Software must be complete and as near to the fielded version as possible when the OT&E is conducted. All associated equipment, publications, training programs, and test/measurement/diagnostic equipment (TMDE) should be complete prior to the evaluation.

The evaluated system is usually part of a larger table of organization and equipment (TO&E) and interacts or is supported by other standard systems. These systems must also be representative of those found in an operational environment.

4. Sufficiency

Sufficiency in the OT&E process ensures that the test plan addresses all of the issues specified in the Operational Requirements Document (ORD), the data collection plan provides for sufficient data, and the evaluation plan is sufficient for the system evaluation. The structure of the OT&E vehicles for acquiring and reducing the information is critical for a complete and unbiased evaluation.

The test plan is the key document in determining what data, and under what circumstances data are collected. The test plan is driven by the user provided issues specified in the ORD and the requirements for data supporting the evaluation. Sufficient, unbiased iterations of test events must be accumulated to facilitate the evaluation techniques prescribed in the evaluation plan.

E. SUMMARY

The OT&E process is designed to assess the effectiveness and suitability of systems, concepts, doctrine, and tactics in a realistic, combat environment. The results of OT&E assessments have significant impact on the acquisition of major programs and have visibility at the Congressional level as well as the top echelons of the Army.

The use of M&S in the OT&E process is limited by law. DoD and Army policies, designed to protect the objectivity of OT&E, reflect a bias against the use of M&S. Counterbalancing

that bias are budgetary constraints that negatively impact on the scope of "live" testing.

Advancing technologies have vastly improved the capabilities of modern M&S applications. The next chapter addresses the Army M&S thrusts that are attempting to exploit these advancing technologies.

III. ARMY MODELING AND SIMULATION THRUSTS

A. GENERAL

From the Army's point of view, anything short of actual combat is simulation. Modeling and Simulation (M&S) encompasses applications ranging from simple mathematical or physical models to sophisticated systems integrating three simulation types; "live", "constructive", and "virtual". The three types of simulations are defined below:

1. "live" simulation consists of operations with users employing real equipment in the field
2. "constructive" simulation which deals with wargames, models and analytical tools
3. "virtual" simulation refers to systems and troops in simulators on synthetic battlefields (Singley, 1993, p.35).

This chapter addresses M&S concepts and applications that are currently available or are being planned for use by the Army in the immediate future. The M&S applications described are not the only resources available, but are representative of the technology available and are therefore used to illustrate applications.

The Army's M&S resources have been primarily used in the areas of training, testing, material development, combat development, and analysis. The Army has increased the capability of its high resolution modeling facilities and is making progress in the area of three dimensional simulation.

These advancements have generated high expectations that, within the next few years, the M&S community will field the requisite fidelity and distributed capabilities needed to streamline the current acquisition process. (Crouch, 1994, p.3)

Technological components of the Army simulation capability include a Distributed Interactive Simulation (DIS) environment transmitted over the Defense Simulation Internet communications network. DIS provides protocols that enable the communication between various models such as Janus (a high resolution constructive model), semi-automated forces (SAFOR) generator, and the Battlefield Distributed Simulation - Developmental (BDS-D) virtual simulator complex.

The highest echelons of Army leadership recognize the need to exploit advanced M&S capabilities for weapon system acquisition in the post-cold war era. In the "*United States Army Posture Statement FY95*", The Honorable Togo D. West, Jr., Secretary of the Army, and Army Chief of Staff General Gordon R. Sullivan state:

The Army will maintain technological superiority through pursuit of promising advanced technologies and concepts, developing new systems when existing systems have reached the end of their useful lives or when a new system offers an essential, revolutionary combat capability. We will exploit Advanced Distributed Simulation for better, more affordable requirements and acquisition testing and will reduce acquisition costs by reducing infrastructure and development cycle times. (West, 1994, p.87)

They also outline two major assets the Army will use to develop weapon systems; the Louisiana Maneuvers (LAM) and the Battle Labs. Both of these assets integrate M&S into the

materiel and concept development process and will be discussed in detail later in this chapter.

B. DoD M&S POLICIES

The Army is adopting policies to take advantage of advanced M&S opportunities. The Army's leaders are setting the M&S policy cornerstones as evidenced by Army Chief of Staff, General Gordon Sullivan's statement:

You need to know that we will use simulation techniques throughout the Army's acquisition process. We will determine needs in large-scale, simulation-supported exercises that allow us to consider alternative solutions that meet our needs. We will use drawings, diagrams and 3-dimensional models generated by computers, put them in constructive or virtual environments, and compare alternatives both technically and tactically. The most promising technologies will be tested by real soldiers, first in reconfigurable crew stations, then in full scale simulations. Final designs, production and assembly steps will also be simulated in virtual factories before actual prototypes are made. Then the actual and virtual prototypes will be exercised simultaneously to discover potential problems before production begins. Tactics, techniques, and procedures are also developed along with the system so that the system is fully ready for use when produced. (Sullivan,1993)

Lieutenant General William H. Forster, the Military Deputy to the Assistant Secretary of the Army (Research, Development and Acquisition), further refined the M&S focus in his 24 May 1993 Memorandum for the Deputy Commanding General, U.S. Army Materiel Command and all Program Executive Officers. Under the subject of "*Simulation Support to the Army*", LTG Forster stated:

The Army Science Board and Defense Science Board have recently studied the potential improvements to DoD acquisition offered by advanced simulation, particularly Distributed Interactive Simulation (DIS). Both concluded that simulation can improve acquisition from concept to fielding through such innovations as: virtual prototyping; engineering simulation; linking of constructive, virtual and/or live simulations; assisting the user in execution of experiments in employment tactics; user test design and critical issue identification; and improved training prior to fielding.

The Army is leading the way for DoD in simulation with such initiatives as Battlefield Distributed Simulation-Developmental, Close Combat Tactical Trainer, and DIS Modernization and Master Plans. We need to take full advantage from concept to fielding. Effective second quarter fiscal year 1994, all Army acquisition strategies for Acquisition Category I and II programs will include a simulation support plan. Additionally, the simulation support plan must be included in the Program Manager's ASARC briefing. Other programs may be tasked by the Army Acquisition Executive to include a simulation support plan. (Forster, 1993, p.1)

Policies integrating M&S into the acquisition process have been initiated from the top levels of the Army. The Battle Labs and LAM have been established and charged with pursuing new technologies and investigating concepts using an integrated M&S approach. Policies for integrating M&S into the OT&E portion of the acquisition process have begun, but not fulfilled.

C. M&S CONCEPTS AND APPLICATIONS

The Army plans to link M&S technological components together through networks such as the Defense Systems Internet (DSI) to create environments like the Distributed Interactive

Simulation (DIS) system. These M&S component concepts and assets are discussed in detail in the following sections.

1. Model-Test-Model

Model-Test-Model (MTM) is a three phase process designed to assist DoD and the Army in conducting more effective and efficient test and evaluation of new weapon systems. The concept envisions the synergistic interaction of testing and modeling to enhance both operational testing and combined arms modeling. The first phase examines the test design to identify possible efficiencies and effectiveness improvements of the design. The second phase examines the conduct of the test to gain insights into potential model-test differences. The final phase focuses on the amount of correlation or association between the model and test results. Based on the amount of correlation, the model may be accredited for a specific trial. Once trials or missions are accredited, test results may be extended beyond test scenarios and conditions which may be cost prohibitive or constrained for environmental or safety reasons. (IR MTM,1994)

A basic building block of MTM is a model, which is defined as:

A representation of an actual or conceptual system that involves mathematics, logical expressions, or computer simulations that can be used to predict how the system might perform or survive under various conditions or in a range of hostile environments. (DSMC TEMG,1988,p.B-8)

2. Janus Combat Model

Janus is a computer-based, two-sided combat simulation model. Janus UNIX 3.17, and Janus Virtual Memory System (VMS) 4.0, are the most recent versions of the model that are now in common use. (Pate,1992,p.2)

The Janus combat model accommodates up to 600 individual combat systems, including up to 100 indirect fire systems, for both threat and friendly forces. All systems are capable of moving, detecting, and firing over a 50 square kilometer, three dimensional terrain representation. Combat systems ranging from major individual fighting platforms such as tanks and helicopters to dismounted infantry, are portrayed using the attributes of the real or notional systems being modeled (e.g., size, speed, sensors, armament, ballistic protection, thermal/optical contrast, etc.). The vulnerability of each system is characterized by data sets of probability of hit (P_H) and probability of kill (P_K) that individually associate each combat system with each weapon in the simulation. (Crooks,1992)

Janus, because of its high resolution capabilities, has been primarily used in aiding analysts with Cost and Operational Effectiveness Analysis (COEA) and combat development system studies such as the 9th Infantry Division (Motorized) force design. Recently, the concept of integrating a constructive model (Janus) with a virtual simulation environment was explored. One of the Anti-Armor

Advanced Technology Demonstration thrusts is to merge constructive and virtual simulation worlds. This allows the orchestration of selected forces, within the virtual simulation environment, to be controlled from a constructive model such as Janus. This orchestration is referred to as semi-automated forces. (Crouch,1994,pp.49-50)

3. Semi-Automated Forces

The semi-automated forces (SAFOR) capability allows a single individual operating a constructive model to control various sized units such as platoons, companies, or battalions within a virtual simulation. These forces appear on the virtual battlefield just as manned simulators do; the fact that they are SAFOR is transparent to the other participants. To keep costs associated with experiments within budgetary constraints, SAFOR can be used to represent both friendly (adjacent, supporting, higher echelon and lower echelon elements) and threat forces. (Loral,1992,p.2)

SAFOR is useful from both a command and control and a cost savings perspective. Command and control is enhanced by the capability to control several systems on the virtual battlefield from a constructive model. Savings are derived from constructive models that generate a system on the virtual battlefield at a lower cost than those generated by virtual networks such as BDS-D. (Crouch,1994,p.51)

4. Battlefield Distributed Simulation - Developmental

Battlefield Distributed Simulation - Developmental (BDS-D) provides the technological framework to conduct a simulated battlefield over a distributed network. Through this system, individuals can fight and analyze the effectiveness differences resulting from the changes made in equipment, doctrine, tactics, organizations, and training methods. The sequence of the battle can be recorded and later analyzed in detail to refine those changes.

The supporting technologies create a simulated or "virtual" battlefield on which users can conduct cost effective experiments or training exercises. The exercises are conducted using actual soldiers operating simulators, permitting soldier-in-the-loop experimentation. Through a combination of local area and extended distance networks, soldiers operating simulators at one site are able to see and interact with soldiers operating at other sites on a common digitized battlefield. (Loral,1992,p.3)

The BDS-D program is sponsored by the U.S. Army and the Commander, U.S. Army Simulation, Training, and Instrumentation Command (STRICOM) is the Program Manager for the BDS-D effort. STRICOM provides the focal point between DoD agencies, user agencies, industry, and the BDS-D sites. (Loral,1992,p.4)

BDS-D will support experiments and evaluations in a variety of areas. Using the approach of simulating before and

during procurement of a new weapon system, users are able to experiment with the weapon system design throughout its acquisition life cycle. For example, developers can perform the following:

- Define requirements accurately and assess trade-offs.
- Explore the capabilities that should be incorporated into a new or existing system.
- Investigate the density and allocation of the system that achieves optimum performance on the battlefield.
- Determine the best means to employ the system once it is built (Loral,1992,p.4).

Users can experiment with new and innovative ways of employing weapon systems so that they better realize their design potentials. Changes in organizational structure can also be analyzed to determine the relative effectiveness on the battlefield of competing organizations. (Loral,1992,p.4)

Local area networks consisting of low cost battlefield simulators, and simulations of experimental systems, and SAFOR are required to facilitate this effort. These simulators will be linked together through a network such as DSI to provide virtual combat operations in the DIS environment for materiel and combat development, and operational testing exercises. (Kelly,1993,p.19)

5. Distributed Interactive Simulation

One of the challenges is integrating constructive and virtual simulation technologies. The dissimilar computer

systems and simulators that the Army intends to combine into one integrated network were not designed to communicate with one another. To achieve this desired seamless simulation capability, a simulated environment that provides standard terms and protocols which allows these different computer systems and simulators to communicate is required. The standardization of terms is achieved by Distributed Interactive Simulation (DIS) Protocol Data Units (PDUs). (Crouch,1994,p.56)

DIS creates a synthetic environment within which humans may interact through simulation at multiple, networked sites using compliant architecture, modeling, protocols, standards, and data bases. DIS and its PDUs are the next generation of distributed simulation evolving from the Advanced Research Project Agency's (ARPA) research project of the 1980's known as Simulation Network (SIMNET). The DIS is in its initial stages with many obstacles yet to overcome. (IST,1993,p.4)

DIS will take advantage of currently installed and future simulations manufactured by different organizations. Consequently, interoperability between dissimilar simulations is absolutely required. The first step in achieving this interoperability is to develop a communications protocol. There must be a standard set of messages that communicate between host computers, the states of simulated and real

entities, and their interactions. This information is communicated through DIS PDUs. (IST,1993,p.8)

6. Defense Simulation Internet

DIS operations are supported by a communication system known as the Defense Simulation Internet (DSI). This communication system was developed, and is currently operated by Advanced Research Projects Agency. The DSI consists of commercial telephone circuits over existing networks with nodes at user locations, and strategically placed switching nodes (Fix East and Fix West) with a central controlling facility in Chicago, Illinois. Connectivity is made with military and civilian satellites to allow worldwide, simultaneous DIS operations. (DIS MODPLAN,1993,p.2)

There are approximately 30 DSI nodes supporting all Services' command posts, Battle Simulation Centers, test beds, Battle Labs, research centers, unified commands, and civilian contractors that support the military. The DSI is expected to expand over the next year with approximately 25 additional sites. (DIS MODPLAN,1993,p.2)

Each location connected to the DSI network is referred to as a DSI node. The Army operates two TRADOC Battle Lab nodes on the DSI; Fort Knox and Fort Rucker with Fort Rucker designated as a Battle Lab support facility. Eventually the Army wishes to operate six to eight Army Battle Lab nodes and

additional communications nodes at most major commands throughout the Army. (Singley,1993,p.37)

Through the interpretive capabilities of DIS and the communication network established by the DSI, the Army will attempt to link constructive models such as Janus with virtual simulation networks such as BDS-D. (Crouch,1994,p.57)

D. BATTLE LABS

TRADOC has organized six Battle Labs to identify, develop, and experiment with new warfighting concepts and new capabilities offered by emerging technologies. The Battle labs are distributed as depicted in Figure 4.

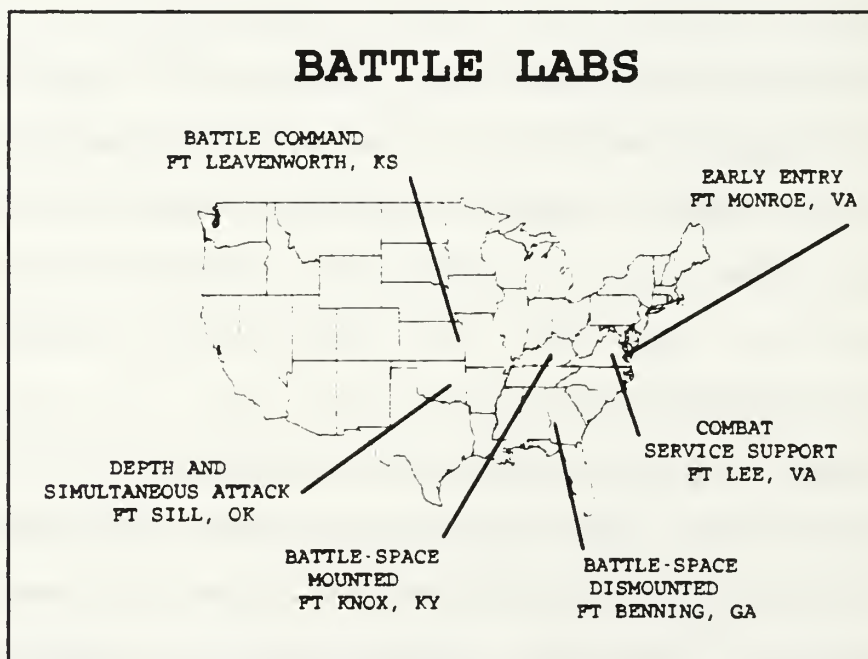


Figure 4 Battle Labs

The Battle Labs initiative is a response to the unpredictability of the post-cold war world. The wide variety and rapidly changing array of direct and indirect threat situations have replaced the single, well-defined threat of the Warsaw Pact which drove doctrine and materiel requirements during the cold-war era. (BLG,1993,p.3)

Battle Labs maintain the Army perspective across a wide spectrum of ideas and concepts to ensure that the Army remains dominant on future battlefields. Through conceptualizing, analyzing, simulating, testing, and evaluating projects, Battle Labs aggressively seek out emerging concepts and technologies worldwide. They streamline the Army planning process by providing an organized way to define requirements; allowing industry to develop a focus for developmental work; providing industry access to a pool of Army thinkers who can delineate ideas about modernization alternatives; and linking combat lessons learned, exercise results, and insights from the regional Commanders in Chief to a formal analytical testbed. (West,1994,p.78)

Battle Labs will be linked through the DSI to each other, the Army R&D Community, sister Services, DoD, and national agencies. All are organizing to take advantage of the DIS technology, which was not available to earlier test-bed operations. BDS-D networks will allow warfighting experts at TRADOC Centers to advance ideas and test them by simulation at a number of locations. (BLG,1993,p.4)

Battle Labs will provide the tools and standards to simulate activities, at a high level of realism, from theaters of war to factories and manufacturing processes. The mechanism for entry into the synthetic battlefields has been limited to a few networked simulators and individual workstations. These will be greatly expanded in the 1990s to include the reconfigurable BDS-D simulators that will provide the desired mix of real ranges, virtual simulations and aggregated constructive simulations into wargame representations. Multipurpose surrogates, such as SAFOR, supported by computer emulation, will allow soldiers to participate or to be simulated in battles. (BLG,1993,p.6)

Simulation tools and methodologies integrated into Battle Labs offer industry a new area of innovative development that has potential beyond its military application. The use of concurrent engineering principles reduces development time and speeds the acquisition process. Virtual prototypes will be produced, so design and manufacturing tradeoffs can be evaluated. Eventually the manufacturing process, the military system, and the system's performance may all be modeled and refined before the first piece of hardware is built. (BLG,1993,p.6)

Synthetic environments will not completely replace hardware demonstrations as a means of introducing new capabilities to the user. However, given the increased costs of hardware development and test, contrasted with the

decreased costs and increasing fidelity of reconfigurable simulators, synthetic environments become ever more appealing. (BLG,1993,p.7)

Battle Labs will help prepare the Army for the challenges of the next century. Unlike the manpower-intensive Louisiana Maneuvers of the 1940s, simulation and Battle Labs will afford a basis for the Louisiana Maneuvers of the 1990s and beyond. (Ross,1993,p.18)

E. LOUISIANA MANEUVERS

The term Louisiana Maneuvers (LAM) refers to a series of large-scale military exercises carried out by Army General George C. Marshall in Louisiana in 1941 to rebuild and renew the Army for combat in World War II. The maneuvers met the challenge by training soldiers, units, and headquarters; validating and improving doctrine and equipment; and testing new units and concepts.

The Army reestablished the LAM in 1992 under a Chief of Staff of the Army charter:

The Louisiana Maneuvers will energize and focus the Army on warfighting and its Title X responsibilities, will provide the Army's senior leadership strategic agility in decision making, and will assess the Army's direction and progress on its journey into the 21st Century.

LAM allows the Army to think, to grow, and to effectively take charge of the process of change. It provides the Army leadership a systematic approach to explore and examine doctrine, organization, training, materiel, leader development, and soldier issues shaping the force for the next century, without putting thousands of soldiers in the field. By harnessing the power of the microprocessor, the

Army will use simulations to develop and produce new equipment, to enhance combat readiness, to train, and to experiment with new ideas. LAM uses exercises, battle laboratories, and other mechanisms to cover the full range of military operations. (West,1994,pp.76-77)

Some major issues that LAM will examine in the near future include an effectiveness review of command, control, communications, computers, and intelligence (C4I) architectures; implications of around-the-clock operations; the impact of new technologies and equipment on the battlefield; deployability, lethality, and survivability of light and heavy forces; the impact of weapons of mass destruction in today's security environment; and a broad range of force generation and deployment requirements. (West,1994,p.77)

Relying heavily upon simulation and modeling technologies, senior Army leaders will use LAM as a tool to help save money by speeding the introduction of promising new weapon systems. This is derived from quickly eliminating unworkable concepts, aiding in the development of new doctrine, and generally guiding the Army as it reshapes itself for meeting post-cold war missions. (Holzer,1993,p.36)

F. SUMMARY

The Army is moving to take advantage of advanced M&S opportunities and the potential cost savings M&S offers in a fiscally constrained post-cold war era. The Army's leadership is setting policies that endorse M&S proliferation Army wide,

including in the costly acquisition process. As a vital part of the acquisition process, how can OT&E integrate M&S concepts and applications to address recurring problems and shortcomings, and enhance the OT&E process?

IV. ANALYSIS

A. GENERAL

The OT&E community has a most difficult role in defining when, where and how it can participate outside the live environment. Operational testers find themselves caught between United States Code, Title 10 mandates and the spiral of diminishing defense dollars. This is a most dangerous position. (Crouch,1994,p.86)

The "most dangerous position" refers to a situation where the OT&E independent evaluator (OPTEC) does not integrate M&S and continues to use expensive live testing, while materiel and combat developers push for OT&E certification based on their own, cost effective operational M&S applications. Although undesirable, the loss of the independent OT&E view could result from the continuing economic pressures in the post-cold war era.

The Defense Modeling and Simulation Office (DMSO) is funding simulation efforts to test the merits of using other-than-live environments for operational testing. The customers for this effort are primarily the materiel and combat development communities. Data are still insufficient to assess the current ability to utilize other-than-live environments for operational testing. However, technology

advancements in the immediate future are expected to provide the required simulation fidelity that will make virtual simulation a viable alternative for some early and follow-on portions of operational assessments. (Crouch,1994,p.87)

This chapter examines OT&E issues and problems, and analyzes M&S capabilities to resolve them or reduce their severity. The methodology used and OT&E problem and issue analysis are addressed in the following sections.

B. METHODOLOGY

The major OT&E problems and issues were established by conducting interviews with experienced OT&E professionals assigned to the TEXCOM Experimentation Center (TEC) located at Fort Hunter-Liggett, California. The OT&E problems and issues were identified from OT&Es planned or conducted at TEC, Fort Hunter-Liggett.

1. OT&E Weapon Systems

OT&E tests were planned and conducted on the six weapon systems briefly described below:

- M1A2 Abrams Main Battle Tank. Upgrades to the M1 Abrams include improved computer and armor protection systems. This weapon system is designed to be fielded in armored, mechanized infantry, and cavalry units, ranging from platoon to division sized elements.
- Air-to-Air Target Designator. This device uses laser technology to designate airborne targets for armed scout and attack helicopters assigned to air attack and air cavalry units.
- Multi-Spectral Combat Decoy. This system provides visual and thermal tracked vehicle signatures in a lightweight

kit form for use by armored, mechanized infantry, and counter-intelligence units.

- Mini Eyesafe Laser Infrared Observation System (MELIOS). MELIOS was designed to improve the night observation capabilities for combat, combat support, and combat service support units at every echelon from platoon through corps level.
- Javelin Anti-Tank Missile System. The Javelin is replacing the shoulder-fired Dragon missile system and provides extended range and improved attack attitudes. It will replace all Dragon systems in combat and combat support units from platoon through corps level.
- AH-64D Longbow Apache Helicopter. Upgrades to the AH-64D Apache include improved armament (including Longbow Hellfire missiles), automated systems, engines, and fire control radar. Longbow Apaches will replace attack helicopters currently fielded in attack helicopter units at battalion through corps echelons.

Interviews were also conducted with personnel from OPTEC, TRAC Monterey, and TRAC White Sands Missile Range (WSMR), New Mexico. These interviews identified the level of M&S integration for the OT&E programs examined.

2. OT&E Problem and Issue Categories

The problems and issues are divided into five categories. The five OT&E problem and issue categories include Test Design Validation, Resource Constraints, System Component Stress, Safety and Environmental Concerns, and Data Reliability and Validity. Categories were selected when at least two of the six OT&E programs experienced similar problems and issues. The categories and general types of problems and issues assigned to each are described in the following paragraphs.

a. OT&E Test Design Validation Category

Test issues and problems were categorized under OT&E Test Design Validation when shortcomings were associated with test design errors or omissions. The validation process is designed to ensure that the baseline scenarios and test execution plans satisfy the user and evaluator requirements for data collection, while simultaneously meeting the mandates and guidance for the conduct of OT&Es.

A desired method for test design validation is the use of a pilot test. A pilot test is a rehearsal of test events using test participants, fully instrumented candidate systems, data collection resources, and test ranges and maneuver areas, but excluding data collected from the test report. A pilot test is useful in determining if the data collected address the criterion under consideration for specific events. It usually does not determine whether or not the test design fully addresses all critical issues identified. The pilot test advantages include validation of test scenarios, data collection plans, test facilities, and pre-test training with no test report impact. Disadvantages include time and funding requirements, and early user familiarization with the candidate system, test facilities, and test trial scenarios.

b. Resource Constraints Category

Shortcomings associated with time, personnel, equipment, and funding availability were categorized under Resource Constraints. These shortcomings impact the OT&E test design and scope in terms of realism, environmental diversity, scale of threat and friendly force structures, and number of test event iterations completed. The degree to which resources are constrained determines the operational scope able to be recreated in the live test, and the type and amount of data available for evaluation.

c. System Component Stress Category

Stress is a critical element of the operational environment and stress level reductions on personnel or equipment during OT&E testing have a negative impact on the evaluation. Issues resulting from unrealistic equipment and personnel workloads, threat capabilities encountered, and familiarity with equipment and facilities were categorized under System Component Stress. OT&E test induced stress levels that are not representative of the operational environment increase the risk that evaluations are based on faulty or unrealistic data.

d. Safety and Environmental Concerns Category

Shortcomings resulting from test events that were eliminated or unrealistically controlled because of potential hazards to personnel or release of pollutants into the

environment were categorized under Safety and Environmental Concerns. As the ranges, lethality, and destructive ability of associated systems all increase with new technologies, safety concerns often limit the use of the actual system to very controlled circumstances not representative of a combat environment. Systems that create radioactivity, ozone depleting elements, and other environmentally hazardous by-products are also limited to controlled scenarios.

e. Data Validity and Reliability Category

Issues associated with test data interpretation or unusual test participant qualifications were categorized under Data Validity and Reliability. Live test events contain an infinite number of variables, providing an opportunity for assigning cause to undesirable outcomes and eliminating outliers or biasing data. The degree to which test participants represent typical operational users impacts data validity and reliability.

C. ANALYSIS OF M&S APPLICATION TO OT&E

OT&E problems and issues within each of the identified categories are detailed and the capabilities of M&S applications to resolve them are analyzed in the following paragraphs. The analysis is organized by problem and issue category.

1. TEST DESIGN

The OT&E test design establishes the amount of data and the circumstances in which data are collected. The test design also sets the foundation for the amount of operational realism achieved. Creating realistic, combat conditions in OT&E tests have been hampered by many factors. Resource constraints, discussed in the following section, are a main cause for reduced realism. Accurate TEMP critical issue interpretation and understanding of the environments, scenarios, and forces required to replicate a representative operational environment have also contributed to lack of test realism. The M1A2, Air-to-Air Target Designator, Javelin, and Longbow Apache test designs had significant shortfalls.

a. M1A2 Main Battle Tank

Interviews with TEC personnel indicated that the M1A2 test was limited to an operational microcosm that significantly increased assessment extrapolation risks. Operational deployment of the M1A2 tank at the brigade or divisional levels could not be assessed due to the resource constraints which limited live testing to one battalion sized task force. Battalions deploy, fight, and are supported differently than brigades or divisions.

A constructive simulation, such as Janus, appears to have application in addressing operational test design shortfalls similar to those experienced by the M1A2. Because

of the wide range of force structure, environments, threat forces, and combat intensities that a constructive simulation is capable of addressing, it is useful for assessing operational environments and scenarios beyond the scope of a resource constrained live test.

TRAC White Sands Missile Range (WSMR) used a similar system to assist in the M1A2 OT&E test scenario development. Experiments were designed on a Janus based constructive simulation and experiments were iteratively conducted for predictive analysis. Actual test equipment were instrumented and data were collected on live test trials. Live test iterations were replicated on the simulations and then correlated. The correlated simulations were then used in other environments and scenarios within the M1A2 operational spectrum and analyzed. The insights gained from these simulations were used to assist in the M1A2 OT&E test conducted at TEC. OT&E test events were selected based on the simulated event outcomes that indicated a high probability for obtaining required data to address critical issues. (Payan,1994)

b. Javelin Missile

TEC interviews revealed that battlefield operating systems normally interoperating with Javelin missile systems were not included in the Javelin test plan. Javelin is deployed in conjunction with other anti-armor systems

including tanks, artillery, and close air support. This environment was too expensive and impractical to replicate in a live environment, and was omitted from the test design.

M&S can provide a method for addressing interoperability issues such as those experienced by the Javelin OT&E. Constructive simulations are capable of representing other battlefield operating systems and integrating a candidate system's capabilities so that interoperability issues can be assessed. Virtual simulations provide methods for assessing interoperability issues with personnel operating associated battlefield systems within doctrinal guidelines.

Some M&S efforts assisted in the Javelin OT&E test design. A MTM pre-test model conducted on the Javelin program successfully correlated live OT&E test data with models generated on Janus. Three scenarios with six missions each were conducted on the model including offensive and defensive Javelin employments. These resulting data provided Javelin employment assessments in an operational environment and OT&E test scenarios were changed to incorporate the MTM recommendations. Integrating MTM efforts into future OT&E test designs can improve test scenarios and environments, and therefore, enhance operational assessments. (IR MTM,1993)

c. Air-to-Air Target Designator

Interviews with TEC personnel indicated the Air-to-Air Target Designator OT&E test design validation process was not totally effective. The test design validation consisted of a paperwork review of the user and evaluator data requirements matched against the test design plan. A pilot test was not conducted and the best judgment of experienced, professional OT&E personnel was used to validate the test design plan. A test matrix was constructed, like the simplified illustration in Table 1.

TABLE 1 OPERATIONAL TEST MATRIX EXAMPLE

Test Events:	Daylight Live Fire	Night Live Fire	96 Hour Field Training Exercise
Issues:			
Can the system be effectively employed with night vision equipment?		X	X
Can the system be operated in degraded modes?	X	X	X
Is the system supportable by user personnel?	X	X	X

Operational test events that were used to address correlating critical issues are designated with an "X". The matrix was useful in ensuring that all data collection requirements were addressed in one or more test design events. However, this paperwork review was not efficient at validating the scenarios and environments required to fully address the issues.

The Air-to-Air Target Designator test design plan validated in this manner had serious shortcomings that were solved during the test execution. Night operations were specified for the Air-to-Air designator OT&E. Because night operations were omitted from the design, a major test event rescheduling was required to accommodate the night environments specified. (TEXC Int,1994)

An OT&E test design simulated on a constructive simulation appears to provide a method for validating the test design plan. The critical issues could be input into the simulation and simulated test trials conducted. Scenarios could then be adjusted to accommodate all critical issues before live test events begin, eliminating shortfalls such as those experienced during the Air-to-Air Target Designator OT&E test.

M&S was used in the Air-to-Air Target Designator OT&E test design. The program used constructive simulations to design the two-on-two test scenarios. However, no simulation generated data were used for the report. M&S was used to assist in operational test scenario development and

test scenarios resulting from the simulations were successfully implemented.

d. AH-64D Longbow Apache

TEC interviews revealed that the Longbow Apache OT&E test design had threat realism shortfalls. The test design did not provide for many of the threat assets expected in an operational environment. Planned threat air defense were under-represented and lacked realistic electronic jamming capabilities. Threat air assets were under-represented and excluded from many planned test scenarios.

M&S could provide methods for addressing threat realism shortfalls in OT&E test designs. Constructive simulations can replicate the full range of threat capabilities expected in an operational environment. Additionally, virtual simulations, incorporating SAFOR, can provide a means to include man-in-the-loop threat forces employed by human beings using doctrinally correct threat tactics.

M&S was used in the Longbow Apache OT&E test design process. TEXCOM validated the scenarios for the test plan using Janus constructive simulations. In addition, the Longbow Hellfire missile was examined in various electronic warfare counter measure situations using a hardware-in-the-loop simulation. These pre-test simulations were used to establish Hellfire P_E and P_K probabilities for casualty

assessments. The success of the M&S assisted Longbow Apache operational testing indicates that M&S integration can improve the test design process.

e. Test Design Summary

In virtually all OT&Es, live testing represents only a small operational microcosm for the candidate system and data collected are therefore, limited to that microcosm. Live operational test evaluations are limited to these data collected. Operational assessments beyond the test scope must be extrapolated to address the system's combat effectiveness and suitability. As the scope of live testing is reduced, the evaluation validity to the operational environments not addressed remains unknown and risk increases.

M&S integration into the OT&E test design appears to provide an opportunity for addressing areas that are beyond the scope of the planned testing. M&S applications, including MTM, constructive simulations, and virtual simulations such as the Hellfire hardware-in-the-loop, can enhance the OT&E test design process. Candidate systems in a constructive or integrated simulation, are able to be portrayed at every echelon in the Army structure, under varying physical and threat environments, and interoperating with other battlefield and logistics systems.

2. RESOURCE CONSTRAINTS

Declining DoD budgets increase the pressure to limit the scope of testing and the realism that can be included in a live test. Resource Constraints had a negative impact on the M1A2, Air-to-Air Target Designator, Multi-Spectral Combat Decoy, and Javelin tests.

a. M1A2 Main Battle Tank, Air-to-Air Target Designator, and Javelin Missile

TEC interviews indicated that these systems were tested at the small unit level, so the interoperability and impact on higher echelon units could not be ascertained by the OT&E tests conducted. Similarly, resource constraints limited the inclusion of associated battlefield operating systems and support elements that would normally be deployed in a combat environment. Interoperability issues with those systems cannot be addressed from test data collected. For example, recovering and evacuating an M1A2 tank from the battlefield to the corps level general support maintenance unit requires significant recovery and transportation assets as well as multi-echelon coordination. M1A2 OT&E test resource constraints did not allow this scenario to be addressed beyond the participating battalion's organic recovery capabilities. (TEXC Int.1994)

Interoperability with other systems beyond the scope of live testing can be partially assessed through M&S.

For example, the TRAC WSMR simulations addressed M1A2 capabilities in various environments and scenarios beyond the scope of the live trials. Using similar applications, the M1A2 could be portrayed interoperating with close air support, artillery and any other battlefield operating system including critical logistics support activities. This capability is clearly outside of the live test environment's resource constrained limits.

M&S appears to have application in addressing OT&E test shortfalls created by resource constraints. The marginal cost of M&S generated operational events is extremely low as compared to those same events conducted in the live environment. Resource constraints that have a considerable impact on the planning of live events, become negligible in the M&S environment.

An example of the wide disparity between live and M&S resource requirements involves M1 main battle tank prototypes. In 1984, evaluations of possible improvements on the M1 Abrams tank were carried out by using real tanks in a live environment. The effort took 24 months and cost \$40 million. A later effort in 1986 used a modified aircraft dome simulator, took only six months and cost \$1 million. In 1992, using DIS, four variations of the M1 Abrams were operated against potential threats, taking only three months and costing \$640,000. The use of M&S can reduce resource constraint impacts by providing more cost effective methods

for assessing candidate systems' operational characteristics.
(Berry,1992)

b. Multi-Spectral Combat Decoy

Interviews with TEC OT&E test officers revealed that resource constraints limited the scale of threat forces planned to be portrayed during Multi-Spectral Combat Decoy test events. The system was not subjected to the full range of threat detection capabilities that would be expected in an operational environment. Threat observation systems were limited to visual, thermal, and radar systems, excluding the extended range of electro-optical systems available to potential threat forces. (TEXC Int,1994)

M&S appears to provide a method of addressing threat assets beyond the scope of live testing. Using the expected detection parameters of the combat decoys, test trials in a virtual environment provides data for threat capabilities that cannot be represented in a live environment. However, the differences in observation cross sections between actual and decoy systems must be quantifiable and verifiable.

c. Resource Constraint Summary

Resource limitations impacted realism and reduced the scope of the live operational test performed. Reduced realism resulted in evaluations that were based on data collected from test trials that were not strictly representative of the operational system, fielded in typical

Army units, in a combat environment. Reduced scope resulted in less quantitative and more qualitative evaluations on the candidate systems.

- Virtual and constructive simulations can enhance OT&E tests that have been negatively impacted by resource constraints. Virtual simulations can provide methods for representing threat and friendly force capabilities that are too expensive or impractical to replicate in a live operational test environment. Constructive simulations can provide a means to assess portions of the operational spectrum outside of the scope of the live test.

3. SYSTEM COMPONENT STRESS

The stress imposed on personnel and equipment by an operational combat environment cannot be replicated through constructive, virtual, or live simulation. Therefore, live testing, while replicating the combat environment, is the most desirable, but most expensive substitute. TEC interviews revealed that personnel and equipment components were not stressed to levels expected in an operational environment in the Air-to-Air Target Designator, Longbow Apache, and MELIOS OT&Es.

a. Air-to-Air Target Designator and AH-64D Longbow Apache

The Air-to-Air Target Designator test was planned for two-on-two engagements, but the operational capability of

the designator specified force ratios of up to two-on-six engagements. Helicopter crews in both tests had limited duty cycles, not representative of an operational combat environment. In addition, the same ranges and maneuver spaces used for operational test participant training were used for test trials. Familiarity with test facilities were considered to improve reactions, decisions, and weapons accuracy. As previously discussed, threat capabilities were under-represented which also reduced personnel stress in these tests. (TEXC Int,1994)

M&S provides methods for enhancing personnel stress without creating dangerous environments. Virtual simulations, integrating operational pilots on flight simulators with SAFOR simulated threat aircraft, would provide the stress associated with multiple aircraft engagements. Missions could also be extended to combat durations using simulations without jeopardizing crews or equipment. Data resulting would reflect more realistic personnel stress levels than are possible in a peace time environment.

Training test participants via virtual simulations preserves personnel stresses induced by unfamiliar environments. Training could also be accomplished through distributed simulations using actual equipment.

Threat induced personnel stress is enhanced through M&S integration. M&S applications provide the full range of threat capabilities. Simulations like BDS-D and SAFOR, have

the requisite threat signatures and capabilities. Test participants operating in virtual or integrated simulations can be opposed by the full threat capacity, controlled by thinking human beings in realistic environments. These threat forces are often more realistically reproduced in M&S than is practical in a live environment. Integrating virtual simulations enhances the stress on test participants to more realistic levels, therefore, operational assessments are more accurate.

b. MELIOS

MELIOS experienced limitations in the degree to which personnel were realistically stressed. Duty cycles for the MELIOS test trials were considerably shorter than the specified operational cycle. System induced fatigue effects on operators was not determined.

Conducting trials with operational users through virtual simulations provides a means to extend duty cycles when similar live testing cannot be accommodated. The impact of more representative fatigue can be assessed from M&S generated data. The risks to personnel and equipment from fatigued operators is minimized by conducting extended duty cycles on virtual simulations rather than on actual equipment.

c. System Component Stress Summary

The stress imposed on personnel and equipment by an operational combat environment cannot be replicated through

constructive, virtual, or live simulation. Live simulation of the combat environment is the most desirable and most expensive means of conducting OT&E. However, the live test addresses only a small microcosm of the operational environment spectrum.

M&S integration appears to provide a means to preserve some personnel stress in the conduct of actual live test trials. Virtual simulations using SAFOR can provide representative threat capabilities which could contribute to threat induced personnel stress. Training test participants through virtual and distributed simulations could also preserve some personnel stress associated with unfamiliar environments.

4. SAFETY AND ENVIRONMENTAL CONCERNS

Managing the safety and environmental impacts of new technology testing, negatively impacts on the successful creation of a realistic combat environment where safety and environmental side effects are not so important. Safety and environmental issues affected the M1A2, Air-to-Air Target Designator, Javelin, and Longbow Apache OT&E tests.

a. Air-to-Air Target Designator and AH-64D Longbow Apache

TEC test officers revealed that peace time crew rest requirements for helicopters in the Air-to-Air Target Designator and Longbow Apache tests were strictly adhered to.

These crew rest requirements are not representative of combat crew duty cycles, which are not constrained to peace time training restrictions. As previously mentioned, safety concerns associated with maneuvering more than four aircraft in close airspace limited Air-to-Air Target Designator trials to two-on-two engagements.

M&S applications providing safe environments could be used to assess the impact of extended operations on aircraft crews. Safety concerns make this the only practical method for obtaining this type of operational data.

With no actual threat to the safety of soldiers, safety considerations are nearly non-existent in M&S applications. For example, relatively close air-to-air combat involving more than the safety constrained two-on-two force ratios are probable in an operational environment. Virtual or constructive simulations provide a means to address issues involving more than two-on-two force ratios. While realism is reduced, safety and environmental concerns are accommodated through M&S integration without the total loss of data.

b. M1A2 Main Battle Tank, Javelin Missile, and AH-64D Longbow Apache

TEC interviews indicated that live fire ranges limited the operational employment planning for the M1A2, Javelin, and Longbow Apache systems. The ranges used were well-marked for firing limits and oriented the crews toward

target positions. Lasers, in all but the Javelin Missile, were restricted to controlled maneuver and air spaces. These controlled maneuver and air spaces did not provide representative maneuver space or engagement ranges. Environmental concerns eliminated operational firing of depleted uranium M1A2 main gun rounds due to radiation hazards. (TEXC Int,1994)

Both constructive and virtual simulation applications provide environments that are not affected by these types of safety and environmental considerations. As a result, data generated on M&S are not biased by those factors.

c. Safety and Environmental Concerns Summary

Safety and environmental concerns negatively impact on the ability to assess the operational effectiveness and suitability of candidate systems. Integrating M&S into the OT&E process provides a means for assessing issues in an environment that is not constrained by safety and environmental concerns. Virtual and constructive simulation applications can be used to assess issues that cannot be safely or environmentally conducted in a live operational test. When test events are limited in number due to safety or environmental concerns, post-test MTM can provide a method to extend data and enhance operational evaluations.

5. TEST DATA VALIDITY AND RELIABILITY

The myriad of variables present in a live test environment impact on data validity and reliability. The M1A2, Air-to-Air Target Designator, Multi-Spectral Combat Decoy, and MELIOS tests experienced data validity and reliability problems.

a. Multi-Spectral Combat Decoy and MELIOS

TEC interviews indicated that both the Multi-Spectral Combat Decoy and the MELIOS OT&E tests had some unfavorable test event outcomes that were challenged by parties with vested interests in the OT&E test results. Specific events were subsequently omitted or obscured so that test trials reflected more favorable results than had actually occurred. For example, one decoy was identified (as a decoy) by the threat participants because of its location in the maneuver area. A protest was made based on the threat participant's knowledge of the maneuver area and the supposed errant placement of the decoy. The test trial was eliminated from the test report. A MELIOS malfunction was traced to an operator error. The finding was challenged because operator training was conducted which should have prevented the malfunction. Those data were not used in the report.

The uniform quality of M&S generated data appears to enhance the reliability and validity of OT&E data. M&S generated data are less susceptible to interpretation as the

M&S application controls all variables by design. Fully verified, validated and accredited M&S applications specifically designed for data collection produce uniform quality data which should enhance the evaluation process.

b. M1A2 Main Battle Tank and Air-to-Air Target Designator

OT&E personnel at TEC indicated that the M1A2 and Air-to-Air Target Designator tests had problems associated with atypical test participants. The OT&E test participants were tasked from tactical units for the test duration. As they were "representatives" of the tactical unit tasked with support, many were higher quality in terms of training, aptitude, experience, and attitude than typical operational individuals. Conducting the tests with these "golden crews" created some degree of test data bias. For example, the pilots in the Air-to-Air Target Designator test were all senior chief warrant officers (CW3 or CW4) with thousands of flying hours logged. Their pilot skills were considered to be atypically high when compared to less experienced pilots prevalent in the operational environment.

M1A2 test participants were also considered to be atypically qualified. Training and familiarization of the M1A2 test crews were conducted on the same ranges and maneuver areas as the OT&E test trials. Decisions, response times, and

accuracy of weapons firing were considered superior to what could be expected in a combat environment. (TEXC Int,1994)

The distributive nature of DIS provides an opportunity to address the "golden crew" problem. Test participants selected over a wide geographic area and linked together through DIS, can participate without leaving their home station. The tendency to select atypical users at home station would be reduced because participants remain anonymous and are not representing the unit as individuals. The same techniques could be used to train test participants without familiarizing them with the limited test ranges and maneuver areas used for actual test trials. Data collected in this manner would have enhanced validity and reliability, thus improving the evaluation.

c. Data Validity and Reliability Summary

Data validity and reliability are affected by the OT&E test scope, realism achieved, and the degree to which test participants represent typical users. Operational assessments of combat effectiveness and suitability are directly affected by data validity and reliability. Integrating M&S into the OT&E process through the use of MTM, virtual, constructive, and distributed simulations, enhances data reliability and validity, and therefore, assessments become more accurate.

D. SUMMARY

Integration of advanced M&S techniques, technologies, and applications including Model-Test-Model, Janus, BDS-D, SAFOR, and DIS, appears to provide a means of addressing operational issues beyond the scope of resource constrained live testing. M&S appears to provide a vehicle for addressing critical issues that are impossible or impractical to represent in a live environment. Operational realism and system stress appear to be enhanced through M&S application.

Integrating M&S does not replace or eliminate live operational testing, but rather augments and focuses live testing where results would provide the best data for the operational evaluation. The adage "you don't use M&S to identify what is exactly right, you use it to eliminate what is exactly wrong" applies to OT&E planning. Integrating M&S into OT&E planning reduces variability by examining critical issues across the operational spectrum replicated on a simulation.

V. CONCLUSIONS AND RECOMMENDATIONS

A. INTRODUCTION

This thesis focused on opportunities to integrate M&S concepts and applications into the Army OT&E process. Recurring OT&E problems and issues were examined and possible M&S based enhancements and solutions were identified. Army OT&E process improvements through M&S integration were analyzed.

The OT&E process has a major impact on candidate systems' critical acquisition decisions. From early operational assessments through the formal operational evaluation, the insights to the systems' operational characteristics are based on OT&Es. The accuracy of these OT&Es in predicting how systems will operate in a combat environment directly impacts on future mission accomplishment, and equally important, the survival of the combat troops who depend upon those systems.

The importance of OT&Es in the acquisition process is underscored by the Congressional interest in the OT&E process and results. OT&E assessments are reported directly to Congress from independent OT&E sources through the DOTE. Continued program authorization and funding decisions are influenced by the operational information provided.

M&S integration into the OT&E process has traditionally been limited. In the past, M&S maturity was limited to physical models and mathematical simulations. Advancements in supporting areas from software to communications networks have resulted in explosive M&S growth and maturity. However, the OT&E community has been slow to integrate this advanced M&S due to the desire to protect their independent status and the perceived negative connotation associated with anything "simulated" in a testing environment.

B. GENERAL CONCLUSIONS

Operational combat effects on personnel and equipment cannot be wholly replicated through constructive simulation, virtual simulation, or live operational testing. Live testing of the combat environment provides the closest possible substitute. It is the most desirable, but most expensive method for addressing OT&E critical issues. M&S cannot, and should not be used in place of necessary OT&E live testing. However, M&S applications offer methods of augmenting and enhancing the OT&E process that merit consideration.

The requirement to create holistic, representative operational environments conflicts with the realities of reduced current and projected defense funding authorizations. The tremendous costs associated with conducting realistic, comprehensive OT&Es makes them susceptible to reduced funding pressures. Army budgets are projected to continue the present

downward trend, which will not improve the prospects for expanding OT&E live testing.

Interviews and other investigations indicate that there are significant problems and issues associated with the Army OT&E process. These recurring problems and issues negatively impact on OT&E abilities to adequately assess the combat effectiveness and suitability of candidate systems, as required by law. Because of the identified problems and issues, OT&E tends to yield more favorable assessments than are likely to be found when the systems are employed in combat. This can lead to the funding of weapon systems whose operational effectiveness and suitability have not been demonstrated.

The integration of M&S including MTM, constructive simulations, SAFOR, virtual simulations, and distributed simulations can provide some solutions to recurring OT&E problems and issues. M&S cannot fully represent the personnel stresses associated with combat environments. M&S cannot replicate the infinite number of variables present in live environments. However, integrating M&S into the OT&E process can provide valuable insights into the operational environment beyond the scope of a resource constrained, live operational test.

C. SPECIFIC CONCLUSIONS

Specific Conclusions regarding M&S application in addressing OT&E recurring problems and issues are presented in the following paragraphs.

1. Test Design

a. Current Problems and Issues

Interviews with OT&E professionals at TEC indicated the following OT&E test design recurring problems and issues:

- It is generally impossible or impractical to portray the full range of force structures, interoperating systems, and potential threat capabilities faced by even the most basic system.
- The current methods for planning the OT&E test, and validating that plan are not efficient or effective.

b. M&S Solutions

Integrating M&S into the OT&E test design process can assist planners in addressing the problems and issues, specifically:

- Constructive simulations can provide a means of examining the candidate system's entire operational spectrum. Force structures, interoperating systems, and threat capabilities can be represented in the constructive environment.
- Integrating planned OT&E live test events with constructive simulations and Model-Test-Model applications can identify scenarios and environments required to address critical issues.

2. Resource Constraints

a. Current Problems and Issues

TEC interviews revealed the following recurring problems and issues associated with resource constraints:

- Resource constraints limit the scope of OT&E live testing.
- The operational microcosm considered shrinks as resources are constrained. This increases the risk that the OT&E will neither accurately nor adequately address the combat operational environment that potential weapon systems might experience.
- Resource constraints limit the degree to which realism is recreated in a live environment.

b. M&S Solutions

Integrating M&S into OT&E testing can reduce the impact created by resource constraints:

- Constructive and virtual simulations can provide methods for OT&E to address operational issues beyond the scope of resource constrained live testing.
- M&S applications are more cost effective than live test events and therefore, are less susceptible to the negative effects resulting from resource constraints.
- Virtual simulations accommodate actual users in an unconstrained environment. This provides critical user responses in environments with realistic threat capabilities, interoperability with other battlefield operating systems, and force structures impossible to replicate in a live environment.

3. System Component Stress

a. Current Problems and Issues

OT&E test personnel at TEC identified the following problems and issues related to system component stress:

- Stress on OT&E test participants and equipment is usually not commensurate with levels expected in an operational environment.
- Resource constraints that limit threat capabilities, workload, and required interoperability functions, may reduce stress to unrealistic levels in the live environment.

b. M&S Solutions

M&S integration can preserve or restore more realistic personnel stress levels to OT&E test participants, specifically:

- Virtual and distributed simulations, used as a training vehicle for test participants, can preserve the stresses associated with unfamiliar weapons engagement ranges and maneuver areas used exclusively for live test trials.
- Threat forces represented on virtual and constructive simulations, can restore the stress of confronting test participants with the full range and capability of representative threat forces, operated by threat expert personnel.
- Stimulators can provide equipment stress for software intensive and communications systems. Other forms of equipment related physical stress cannot be reproduced through M&S applications.

4. Safety and Environmental

a. Current Problems and Issues

TEC interviews identified the following safety and environmental issues that increasingly limit the ability to fully consider OT&E critical issues in a live environment:

- New technology advancements including lasers, depleted uranium projectiles, and other potentially hazardous systems cannot be addressed in an unrestricted, live operational test.

- Systems that produce environmentally hazardous by-products are restricted to very controlled scenarios, not representative of a combat environment.
- Peace time safety requirements that are significantly more restrictive than those expected in a combat environment, negatively impact OT&E assessments.

b. M&S Solutions

Integrating M&S into the OT&E process can provide solutions for data collection when scenarios are restricted by safety or environmental concerns:

- M&S can provide a means to address critical issues that are too hazardous or environmentally polluting to conduct in a live test. In extreme situations, M&S may provide the only OT&E data obtainable for OT&E consideration.

5. Data Validity and Reliability

a. Current Problems and Issues

Interviews with TEC OT&E personnel revealed the following data validity and reliability problems and issues:

- Data collected from the OT&E microcosm must be extrapolated to the operational spectrum not addressed within the live OT&E scope. As OT&E test scope becomes smaller and more constrained, data validity and reliability risks increase.
- The myriad of variables present in a live OT&E environment invites questionable interpretation of the results. False causes may be assigned to some undesirable events that eliminate, obscure, or reduce the severity of the failure.
- OT&E test participants are often not representative of the typical operational user. Data validity and reliability suffer when "golden crews" (personnel who are atypically high in aptitude and attitude) are used to represent the "typical" user.
- Training test participants on the same ranges and maneuver areas used for OT&E test trials creates unrealistic responses. This familiarity improves response times, anticipation, and weapons accuracy.

b. M&S Solutions

Integrating M&S into the OT&E process can assist in addressing data validity and reliability related problems and issues:

- M&S applications can provide a means to augment data required for quantitative evaluation.
- Data generated on M&S applications have controlled variables, virtually eliminating the opportunity for event interpretation and manipulation.
- DIS can provide an effective means for addressing the "golden crew" problem. Data collection and test participant training via DIS preserve the actions, reactions, and decisions of representative operational users.

D. RECOMMENDATIONS

Implementing the following recommendations should enable M&S to enhance and improve the Army OT&E process.

1. The Army should continue and expand existing M&S efforts in requirements generation, data augmentation, and OT&E.

Cooperative M&S efforts between OPTEC and TRADOC, such as the M1A2 and Javelin programs, will enhance the OT&E process through early and accurate critical issue identification and test design validation. OT&E test data will be improved and combat effectiveness and suitability assessments will be more accurate.

2. M&S applications that have the fidelity to integrate candidate system capabilities and parameters for OT&E should be developed.

The M&S applications developed should portray existing threat and friendly force structures in varying environments through theater level. These applications should include constructive and virtual simulations capable of examining the impacts on threat capability, battlefield interoperability, and logistics supportability issues. This will provide methods for examining the operational spectrum beyond the live test scope. Extrapolation of live test data via M&S will enhance data and evaluation accuracy.

3. Verification, Validation and Accreditation (VV&A) requirements for previously validated applications should be limited to the candidate systems' capabilities and parameters added.

The VV&A process for M&S applications is time consuming and expensive. M&S applications with standing VV&A approval could enhance M&S integration into the OT&E process.

4. Equipment simulators at user locations should be linked through DIS for virtual simulations integrating a wide variety of typical users for operational assessments.

Test participant training at home station through DIS could improve OT&E data validity during live test trials.

E. FURTHER RESEARCH

Further research is recommended on the following subjects relating to this thesis:

1. Research should be conducted to determine the differences between test participant actions, reactions, and decisions in live versus simulated environments.

The results of this research should help establish the degree to which M&S generated reaction and decision data correlate with live operational testing.

2. Research should be conducted on the impacts of the future digitized battlefield on live and simulated OT&E test events.

The effects of the future digitized battlefield on tactics and user decisions must be replicated in OT&E and related M&S applications. This will be required to accurately portray the operational environment under battlefield digitization in future M&S applications.

3. The compatibility of current and future weapon system training simulation devices with DIS and other M&S architectures should be investigated.

Dual use of training simulation devices for training and OT&E testing via virtual and distributed simulations could enhance the M&S integration into the OT&E process.

4. The integration of artificial intelligence with operationally related M&S applications should be analyzed.

Candidate system employment via artificial intelligence simulations could provide effectiveness and suitability assessments while varying doctrine and tactics. Threat forces controlled through artificial intelligence simulations could provide probable threat adjustments to the employment of candidate weapon systems.

APPENDIX

Acq Acquisition
 ADATS-A Acq and Dev of Threat Simulators Activity
 AFOTEC Air Force Operational Test and Evaluation Command
 AMC Army Materiel Command
 AR Army Regulation
 ARPA Advanced Research Projects Agency
 ASA Assistant Secretary of the Army
 ASA(RD&A) ASA (Research, Development, and Acquisition)
 ASARC Army Systems Acquisition Review Council
 ATD Advanced Technology Demonstration

 BDS-D Battlefield Distributed Simulation - Developmental
 BLG Battle Laboratory Guide

 C4I Cmd, Control, Communications, Computers, Intelligence
 CEP Concept Evaluation Program
 COEA Cost and Operational Effectiveness Analysis

 DAB Defense Acquisition Board
 DIS Distributed Interactive Simulation
 DMSO Defense Modeling and Simulation Office
 DoD Department of Defense
 DoDI DoD Instruction
 DOTE Director of Operational Test and Evaluation
 DSI Defense Simulation Internet
 DT&E Developmental Test and Evaluation
 DUSA Deputy Under Secretary of the Army
 DUSA(OR) DUSA (Operations Research)

 ECM Electronic Counter Measures
 EUTE Early User Test and Evaluation

 FDTE Force Development Testing and Experimentation
 FOTE Follow-on Operational Test and Evaluation
 FY Fiscal Year

 IOTE Initial Operational Test and Evaluation
 IST Institute for Simulation and Training

 JT&E Joint Test and Evaluation

 LAM Louisiana Maneuvers
 LRIP Low Rate Initial Production

LTG Lieutenant General
 M&S Modeling and Simulation
 MELIOS . . . Mini Eyesafe Laser Infrared Observation System
 MS Milestone
 MTM Model-Test-Model
 .
 OEC Operational Evaluation Command
 OPEVAL Operational Evaluation
 OPTEC Operational Test and Evaluation Command
 OR Operations Research
 ORD Operational Requirements Document
 OSD Office of the Secretary of Defense
 OT Operational Test
 OTSA Operational Threat Support Agency
 OT&E Operational Test and Evaluation
 OTEA Operational Test and Evaluation Agency

 P_H Probability of Hit
 P_K Probability of Kill
 PDU Protocol Data Unit

 R&D Research and Development
 RD&A Research, Development and Acquisition
 RDT&E Research, Development, Test & Evaluation

 S&T Science and Technology
 SAFOR Semi-Automated Forces
 SIMNET Simulation Network
 STRICOM . . Simulation, Training and Instrumentation Command

 T&E Test and Evaluation
 TEC TEXCOM Experimentation Center
 TECO Test and Evaluation Coordination Office
 TEMP Test and Evaluation Master Plan
 TEXCOM Test and Experimentation Command
 TMDE Test, Measurement, and Diagnostic Equipment
 TRAC TRADOC Analysis Command
 TRADOC Training and Doctrine Command

 USAPS United States Army Policy Statement
 USC United States Code

 VV&A Verification, Validation, and Accreditation
 VMS Virtual Memory System

LIST OF REFERENCES

Berry, Clifton F., "War Breaker", National Defense, December 1992.

Crooks, William H., and Fraser, Robert E., "Design Data Handbook - SIMNET/Janus Interconnection", IEI Technical Report No. TR-17102-13000-1-05-92, 28 May 1992.

Crouch, Thomas W., "The Impact of Modeling and Simulation on the Army Acquisition Process", Naval Postgraduate School Thesis, March 1994.

Defense Systems Management College, "Test and Evaluation Management Guide", March 1988.

Department of Defense Instruction 5000.2, "Defense Acquisition Management Policies and Procedures", 23 February 1991.

Forster, William H., "Simulation Support to Army Acquisition", Memorandum to the Deputy Commander Army Materiel Command and Program Executive Officers, 24 May 1993.

Holzer, Robert, and Muradian, Vago, "U.S. Army Speeds Simulator Program", Defense News, 7-13 June 1993.

Institute for Simulation and Training, "DIS User's Orientation Guide", May 1993.

Kelly, Valerie, "Topographic Engineering Center Supports Simulation and Training", Army Research, Development, and Acquisition Bulletin, January-February 1993.

LeSueur, Stephen C., "Senators: DoD Reform Undermines Weapon Test Office", Defense News, 10-16 January 1994

Loral Systems Company, "A Guidebook for Agencies Conducting Research Using Battlefield Distributed Simulation - Developmental (BDS-D)", 5 May 1992.

Maze, Rick, "Fallout: Weapons that Don't Work", Army Times, 4 April 1994.

Operational Test and Evaluation Command Handbook 73-21-1, "Pocket Guide to Modeling and Simulation to Support Operational Test and Evaluation", 9 December 1993.

Pate, Charles A., and Proctor, Michael D., "Interim Report on Model-Test-Model in Support of the Javelin IOTE", December 1993.

Pate, Maria C., "Comparison of Janus and Field Test Helicopter Engagement Ranges for the Line-of-Sight Forward Heavy System", Naval Postgraduate School Thesis, December 1992.

Payan, Ferdie, "Telephone Interview", White Sands Missile Range, 15 August 1994.

Ross, Jimmy D., "Legacy for the '90's in Louisiana Maneuvers", Army Magazine, June 1993.

Singley, George T. III, "Distributed Interactive Simulation - A Preview", Army Research, Development, and Acquisition Bulletin, March-April 1993.

TEXCOM Experimentation Center, Combat Experimentation Branch, "Personal Interviews", June 1994.

Trifiletti, Anthony C., "Personal Interview", Naval Postgraduate School, 10 February 1994.

United States Army Materiel Command Public Affairs Office, "How to Do Business with Battle Labs: A Guide for Industry", May 1993.

United States Army Regulation 73-1 (Draft), "Test and Evaluation", Undated.

United States Code, Title 10, 1989.

West, Togo D. Jr., and Sullivan, Gordon R., "Challenges and Opportunities", United States Army Posture Statement FY 95, February 1995.

Williams, Robert H., "Simulation Provides Key to Drawdown Dilemma", National Defense, May-June 1993.

INITIAL DISTRIBUTION LIST

	No. Copies
1. Defense Technical Information Center Cameron Station Alexandria VA 22304-6145	2
2. Library, Code 052 Naval Postgraduate School Monterey CA 93943-5002	2
3. Defense Logistics Studies Information Exchange U.S. Army Logistics Management Center Fort Lee VA 23801-6043	1
4. OASA (RDA) ATTN: SARD-ZAC 103 Army Pentagon Washington DC 20310-0103	1
5. Professor David V. Lamm, Code SM/Lt Department of Systems Management Naval Postgraduate School Monterey CA 93943-5000	5
6. Lieutenant Colonel Brad R. Naegle 304 S. 500 E. Clearfield UT 84015	2
7. Professor Thomas H. Hoivik, Code SM/Ho Department of Systems Management Naval Postgraduate School Monterey, CA 93943-5002	1

GAYLORD S

DUDLEY KNOX LIBRARY



3 2768 00311879 5